Fact Sheet[1]
Carbon Sequestration: A Local Solution with Global Implications

This fact sheet is a resource to inform mine land owners, companies, and other interested stakeholders of the opportunities to utilize reforestation to cleanup and restore former mine lands and generate carbon sequestration credits. It is one in a series of fact sheets that describe a variety of tools that may be used to reuse former mining sites. This fact sheet focuses on one tool, carbon sequestration, its use on former mine lands, and the benefits of reforesting these lands. It also examines the requirements and limitations for pursuing mine land reforestation and sequestration projects and how reforestation projects can fit into emerging markets for carbon trading. Carbon sequestration may be applicable to only a small percentage of former mine lands throughout the country. However, given the number of former mine lands, that small percentage may represent thousands of actual sites.

Introduction

While the debate over climate change continues, Federal and state agencies, industry, and other organizations are pursuing proactive approaches to reducing atmospheric carbon, including carbon sequestration projects. Degraded lands, including former mine lands, are being reforested across the United States. Mine reclamation through reforestation and sustainable forest management can provide two major benefits. Financial benefits include revenue from new forests, job creation, and other impacts on local economies. Environmental benefits include storing carbon in the trees, enhancing wildlife habitat, and improving air and water quality.

Efforts to increase terrestrial carbon sequestration are based on the premise that reforestation adds to the planet's net carbon storage and helps moderate global warming by slowing the growth of carbon emissions in the atmosphere. In a carbon market, each ton of carbon sequestered is called a carbon credit. Using sequestration, companies can buy or generate these credits, which are then sold or traded by companies to offset their own carbon dioxide (CO_2) emissions.

The trees planted on this Alabama mine site have grown to 6 inches in diameter in 10 years. (photo by Office of Surface Mining)

Reforestation and sequestration may not be applicable for all former mine lands. Most of the current experience with reforestation and sequestration has come from coal-mining sites in the Eastern U.S. and the Pacific Northwest. However, reforestation can also be relevant to former mining

[1] This document does not represent official US EPA policy or guidance. Rather this material presents alternative approaches which may lead to environmental improvements at mining sites.

sites disturbed by hard-rock mining. For example, the state of Colorado has recently focused its reforestation activities on abandoned hard rock mines.

In addition, current experience with mine land reforestation suggests that such projects will be more successful in areas with sufficient moisture and where forests existed prior to mining activities. Because of low tree survival and the high cost to plant replacement trees, arid former mining sites may not be suitable candidates for reforestation and sequestration projects.

This fact sheet provides resources for companies and communities interested in reclaiming former mine lands and generating carbon sequestration credits. It details the basics of terrestrial sequestration and the benefits of reclaiming and reforesting these mine lands. This paper also explores how mine land reforestation projects can relate to state and national sequestration programs and worldwide agreements to reduce greenhouse gas emissions. It also discusses the requirements and limitations in pursuing reforestation and sequestration projects on a former mine land.

What is Carbon Sequestration?

Carbon sequestration removes carbon, in the form of carbon dioxide, either directly from the atmosphere or at the tail end of combustion and industrial processes. While there are several types of sequestration, this paper examines the long-term storage of carbon in trees and plants (the terrestrial biosphere). CO_2 removed from the atmosphere is either stored in growing plants in the form of biomass or absorbed by oceans. Sequestering carbon helps to reduce or slow the buildup of carbon dioxide concentrations in the atmosphere. For organizations interested in generating carbon credits, may former mine lands provide the land necessary to plant trees. Appendix A provides additional information on carbon sequestration and the role that terrestrial sequestration plays in reducing or slowing the growth of CO_2 emissions.

Terrestrial sequestration is a form of indirect sequestration whereby ecosystems (e.g., forest and agricultural lands, wetlands) are maintained, enhanced, or manipulated to increase their ability to store carbon.

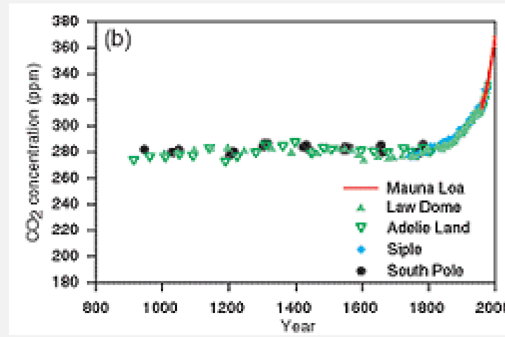
Why is Carbon Sequestration Important

Greenhouse Gas Increases

Before the Industrial Revolution, the concentration of greenhouse gases (GHG) in the atmosphere remained relatively constant. Except for slow changes on geological time scales, the absorption and release of carbon was kept in balance. During that time, changes in biomass and soil organic carbon[2] were the main sources of fluctuation in atmospheric levels of carbon.

[2] Soil organic carbon is carbon residue retained by the soil in humus form. It improves soil structure and the fertility of soil.

By clearing forests and burning fossil fuels more rapidly than the carbon can be sequestered, industrialization may have altered this equilibrium. Currently, human activity is directly or indirectly responsible for the release of six to seven billion metric tons of carbon annually. Since the industrial revolution, CO_2 concentrations in the atmosphere have increased from 290 parts per million (ppm) by volume to greater than 360 ppm. It is expected that atmospheric CO_2 levels will continue to rise and may exceed 500 ppm by 2050. (IPCC 2001)



Atmospheric CO_2 concentrations on a time scale. (Source: IPCC, 2001)

Climate Change

A growing concern is that increases in atmospheric CO_2 concentration may be generating changes, including increases in average global temperature and other climate change impacts. Although some of the effects of increased CO_2 levels on the global climate are uncertain, most scientists agree that doubling atmospheric CO_2 concentrations may cause serious environmental consequences. Rising global temperatures could raise sea levels, change precipitation patterns, and affect both weather and climate conditions.

In light of these potential impacts, strategies to help reverse these emissions trends are increasing in importance. Many state, national, and international governments are taking steps to more effectively manage and slow the growth of their carbon emissions. For many of these governments, terrestrial sequestration is part of a portfolio of approaches to inventory and reduce greenhouse gas emissions. Their experience is demonstrating that establishing new forests can offer cost-effective management options for offsetting carbon emissions, particularly in the near future.


With Mt Rainier in the background, reclamation at this Washington State site includes reforestation that restores the pre-mining forestry land use. (photo by Office of Surface Mining)

The Opportunity for Degraded Lands: Carbon Sequestration on Former Mine Lands

According to the U.S. Department of Energy (see http://www.fe.doe.gov/programs/sequestration/), there are millions of acres of land in the U.S. able to support only limited vegetative cover due to past and present mining activities. The Appalachian coal region alone has nearly one million acres of abandoned mine lands which could benefit from reclamation and reforestation efforts. Currently idle or underutilized, many of these barren or marginally reclaimed lands can provide opportunities to sequester carbon dioxide emissions and generate other environmental benefits.

Reforesting former mine lands can help increase the total number of reclaimed mine sites and improve the quality of the site reclamation. If storing carbon in forests is cheaper than paying a carbon tax or complying with government regulations, companies may choose to grow their own "carbon storing" forests or invest in forests grown by others as a means to sequester carbon or offset emissions. Given their large number of underutilized acres, former mine lands offer potentially significant opportunities to invest in reforestation and accrue benefits from those activities.

> Texas Utilities (TXU). Energy in Texas has established a pioneering reforestation program to deal with its mine lands and to help offset its emissions. Since the program began in 1973, the company has planted over 18 million trees on 25,000 acres. About 50 percent of TXU's reforested area has been developed as wildlife habitat. Habitat was established with a mix of over 40 native hardwood and coniferous tree species.

Benefits of Mine Land Reclamation and Reforestation

Mine reclamation, reforestation, and forest management may provide ecological and economic benefits. Environmental benefits include reclamation of sites and storage of carbon in trees and soil. Financial benefits accrue to landowners and companies. Landowners may receive economic benefits from timber revenues, job creation, and other local economic benefits. Companies can obtain benefits from investing in former mine land reforestation in the form of carbon credits, waste recycling, and public relations.

Environmental Benefits

Beyond carbon sequestration, environmental benefits also include improved of air and water quality, enhanced of wildlife habitat, reduction in soil erosion, and increased recreational opportunities.

Air Quality: Improvements in air quality generated by reforestation extend beyond the sequestration of carbon dioxide. Research has shown that reforestation benefits air quality in other ways. The leaf and needle surfaces of trees remove air pollutants such as nitrogen oxides, ammonia, and sulfur dioxide. Trees also have a role in intercepting or filtering out particulate matter in the air. A study of Chicago air quality concluded that the trees in that city alone produced $9.2 million (1994 dollars) worth of air quality improvements in just one year. (http://216.48.37.142/pubs/viewpub.jsp?index=4285)

Wildlife Habitat: Reforestation of land after it has been disturbed by surface mining can produce valuable wildlife habitat by planting trees. This will in turn generate forest litter, which is an important part of the food chain and enriches the soil. The tree canopy moderates temperatures of rivers and streams, which aids the survival of aquatic species.

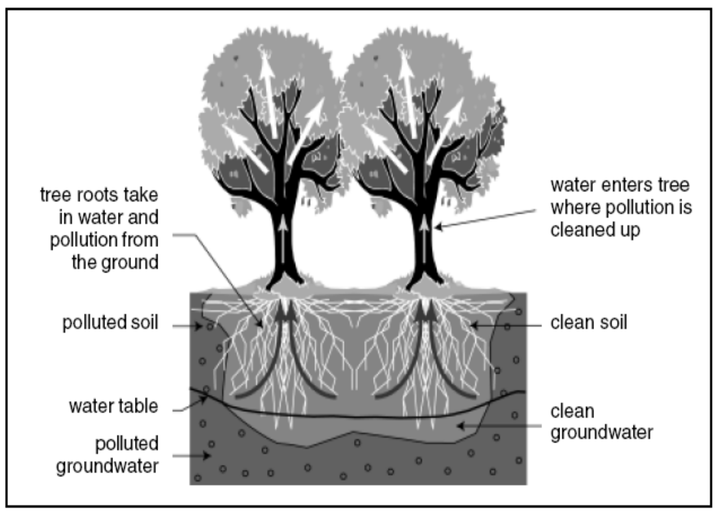
> **Habitat Guidelines** - Some states have established mine reclamation guidelines to encourage the enhancement of fish and wildlife habitat. Kentucky's new abandoned mine land reclamation policies discourage excessive grading and shaping of the land and encourage planting of native vegetation, including ground covers, that have high food value for wildlife and are compatible with tree growth.

Providing habitat for endangered and threatened species is another potential benefit. In some cases, there are governmental incentives for landowners who restore or create habitat crucial for endangered species. The state of Texas has partnered with the U.S. Fish and Wildlife Service to offer landowners reimbursement for habitat restoration. In this program, landowners can be reimbursed for up to 80 percent of their costs for habitat improvements.

Recreational benefits: For local communities, reforested land may provide passive recreational opportunities, such as hunting, hiking and birdwatching.

Erosion and water quality: Reforestation can help remediate former mine lands by improving water quality. Tree roots stabilize mine land soil, which is susceptible to erosion. By stabilizing the soil, trees prevent sediment and nutrients from washing into nearby streams and rivers.

Former mine lands and phytoremediation:[3] Revegetating former mining sites can be viewed as habitat improvement or the creation of a "living cap." In addition, depending on the type of contamination present and the type of trees planted, revegetation can simultaneously provide a phytoremediation contribution. Phytoremediation is the use of vegetation for *in situ* treatment of contaminated soils, sediments, and water. Phytoremediation has an advantage of being less costly than many remediation alternatives. However, the process requires considerable time and should be employed at sites where remediation can occur over a long period of time. For mining sites, phytoremediation should generally be viewed as part of a treatment train, and is generally a "polishing" step.



Source: Clu-In: A Citizen's Guide to PhytoRemediation

It is important to recognize that planting trees for carbon sequestration purposes does not equate to phytoremediation. Depending on the type of trees selected, reforesting a former mine land to generate carbon credits may do nothing to extract or remediate any existing contamination at the site. However, some tree types may serve to phytostabilize the soluble metals in the ground water or soil as well as creating a more suitable growth environment on a formerly uninhabitable mine site. In such cases, there may be opportunities to pursue joint goals of carbon

[3] "Phytoremediation is the use of vegetation for *in situ* treatment of contaminated soils, sediments and water." See *Phtoremediation*, Jerald L. Schnoor, http://www.gwrtac.org/html/tech_eval.html.

sequestration undertaken in conjunction with phytoremediation approaches.

Financial Benefits - Local Economic Benefits

Reforestation of former mine lands has a wide variety of anticipated economic benefits for landowners and nearby communities. Recent research indicates that in many cases, reforestation can be an economically beneficial post-mining land use over the long term. (http://www.mcrcc.osmre.gov/PDF/Forums/MarketBasedReforest/1-7.prn.pdf) Local economic benefits for communities and landowners include revenue from timber, recreational revenue, revenue non-timber products, and tax incentives. An overview of financial benefits is below.

Recreational revenue: Landowners may receive economic benefits from recreational uses on reforested mine lands. For instance, a landowner may collect fees for hunting, skiing, fishing, biking, and other outdoor activities on reforested properties.

Benefits from timber harvests: A number of studies have shown that if appropriate forestry practices are used, reclaimed mine lands can generate productive forests. Researchers from Virginia Tech studied forests on reclaimed mine sites in the Appalachian region and the Midwest and found that these sites could equal or exceed the productivity of unmined lands. The most productive sites had commercial timber values averaging between $6,000 and $8,000 per acre, a figure comparable to timber values on undisturbed sites. The research studied conifers and hardwoods and concluded that the timber value at reclaimed mine sites would be similar to that of non-mined sites for either type of tree. In addition to the direct economic benefits from timber, there can be secondary benefits. Reforestation can create jobs in forest management and other aspects of the timber industry. Job creation and increased property taxes on reforested land can also increase a community's tax base.

Non-timber harvests: Landowners may generate income by harvesting medicinal, ornamental, or edible plants that grow in forested areas.

Tax incentives: States and the federal government offer tax deductions or credits for reforesting land. For example, Mississippi allows landowners to recover up

Federal Tax Credit: The Reforestation Amortization and Tax Credit allows taxpayers to deduct the costs of forestation or reforestation of qualified timber properties. To qualify, the reforested land must be for the commercial production of timber and located in the U.S. The site must be at least one acre in size. Timber grown for personal use does not qualify.

Landowners can deduct reforestation expenses from their taxable income over an eight-year period and receive a direct tax credit of 10 percent of reforestation expenses. Qualifying costs include direct planting costs, site preparation, seedlings, and depreciation on equipment. Wages paid to oneself cannot be included, but wages paid to others, including members of the owner's family, can be included.

Ornamentals, Christmas trees, and nut trees do not qualify for the tax credit.

Information about the Tax credit can be found in the IRS Farmer's Tax Guide. (http://www.irs.gov/pub/irs-pdf/p225.pdf) to half of their investment in reforestation through the Mississippi Reforestation Tax Credit. (See Appendix C for other state programs.) The federal government also offers a tax credit for reforestation projects; individuals can deduct investment in reforestation projects from their federal income taxes.

Financial Benefits - Company Benefits

In addition to local benefits, reforestation and sequestration projects can provide benefits to the companies who fund or invest in these projects. Companies are motivated to invest in reforesting former mine lands because of an expectation that they will control or own any carbon credits created through the reforestation. For companies with carbon intensive operations (e.g., paper companies, electric utilities), investment in mine land reforestation projects can represent a low-cost option for companies to hedge against an uncertain but potentially carbon-constrained future. Benefits are detailed below.

Researchers at Virginia Tech found that by selling carbon credits, landowners could increase their earnings by 10 percent over revenue generated solely by sale of timber products, even when using a conservative price of $3 per ton of carbon.

Carbon credits: Fossil fuels are consumed in large volumes for power generation, industrial processes, and transportation. As large emitters of CO_2, companies such as electric utilities understand they may need to reduce greenhouse gas emissions (GHG). Recognizing this outcome, many utilities are participating in GHG reduction programs. Because market-based emissions trading can offer a low-cost method for managing emissions, companies are beginning to link sequestration projects with the banking and trading of carbon credits.

These carbon credits provide ownership or "rental" rights to the gaseous carbon sequestered in a forest. A company may then buy, sell, or apply the credits to offset its own emissions. Typically ownership rights pertain to the carbon sequestered in a tree–not the tree itself–but this should be clarified on a site-specific basis. Through this market-based approach, organizations can meet their own emission reduction requirements and excess credits can be sold to companies that find it more cost-effective to purchase credits than reduce their own emissions.

TVA's Paradise Fossil Plant tested the application of CCP gypsum byproducts as soil amendments to enhance the growth of trees planted on site. (Source: Tennessee Valley Authority)

Waste recycling: There are countless acres of former mine lands in the U.S. in need of attention to address acid mine drainage (AMD), to stop soil erosion, and to restore the land to more productive use. For many sites, reclamation and reforestation offer an opportunity for beneficial use of coal-combustion products (CCPs), such as fly ash. Coal-fired power plants generate over 118 million tons of fly ash, flue gas desulfurization solids, and other byproducts each year. Only 31 percent of this ash is put to use. The remainder ends up in landfills.

Fly ash produced during the combustion process is high in pH (alkaline) and can be used to buffer AMD in highly acidic soils found at mine sites. The ash neutralizes the soil and provides plant-available nutrients needed for new vegetation and to enhance tree growth. Use of fly ash can provide companies with secondary benefits, including lower disposal costs and less landfill spaced needed for fly ash disposal. The chemical composition of fly ash varies, depending on the type of coal burned, the size of the ash, and the efficiency of smokestack scrubbers. Fly ash is primarily composed of relatively insoluble silicon, aluminum, and iron oxides, but it can also contain soluble metals and metal oxides. When exposed to water, the metals in fly ash could leach into the environment, polluting surface or groundwater. As a result, some fly ash may not suitable for all former mining sites.

Ecological assets are tradeable credits that reflect the economic value that has been assigned to an ecosystem "service."

Allegheny Power provides an example of how reforestation and the development of ecological assets can generate tax benefits. Instead of selling 20,000 acres in West Virginia to private developers, Allegheny sold the property to the U.S. Fish and Wildlife Service for conservation and habitat purposes. By appraising the ecological asset value of the land before the sale, Allegheny received tax benefits based on the difference between the sale price and the land's appraised value.

Other Environmental Credits: In addition to carbon credits, reforestation projects on former mine lands can generate complementary ecological assets, including water quality trading credits, wetlands banks, and endangered species habitat credits. Credits could be sold directly or "banked" for future use. While these credits have ecological and societal values, they also have monetary value for companies. As businesses are in operation to make a profit, reforestation and sequestration projects on former mine lands present new opportunities that are consistent with conventional business strategies.

Carbon Sequestration and Emerging Carbon Markets

There are growing signs of emerging markets for greenhouse gas emissions. An increasing number of national and state governments, corporations, and non-governmental organizations have begun to pioneer carbon offset markets and undertake carbon sequestration and banking projects.

In 1999, BP Amoco announced that it would set an internal target of reducing the company's greenhouse gas emissions 10 percent below 1990 levels by 2010. BP Amoco intends to use a system of company-wide emissions trading to reach its goal.

The following case studies examine how organizations have pursued reforestation and sequestration projects on former mine lands. recognized the potential benefits of sequestration and are putting reforestation of former mine lands and the generation of carbon credits into practice. The following Allegheny Energy case example provides an overview of the process of reforesting an AML, from site selection to site management.

Case Example: Allegheny Energy's Reforestation and Sequestration Pilot

In 2001, Allegheny Energy (Allegheny), in partnership with the U.S. Office of Surface Mining, the U.S. Department of Energy, Pennsylvania Department of Environmental Protection, and several local conservation groups, undertook a reforestation and sequestration pilot project on previously mined land in western Pennsylvania. Allegheny's objectives for this Limestone Run project were threefold:

- test the effectiveness of using fly ash from a local coal-fired power station as a soil amendment for new vegetation;
- test the technical feasibility of reforesting abandoned mine lands for carbon credits; and
- improve wildlife habitat and water quality.

In addition, Allegheny believed the project could foster good public relations with the local community and give the company an opportunity to show its commitment to environmental restoration activities. Company representatives also felt that giving local community members ownership in the outcome of the project, the company was able to make partners out of stakeholders less inclined to support the project.

Site Selection

Allegheny focused its attention on sites close to one of the company's coal-fired power stations. This limited transportation costs for shipping fly ash to the selected site. Abandoned mine lands are prevalent throughout the Appalachian region, so there were many sites from which to choose. However, the company still faced hurdles. Allegheny wanted a site with heavy equipment access. Having fallen into disuse, most sites had poor access. In addition, many sites had grass cover in place that needed to be removed prior to planting. To avoid the problem of dealing with additional site owners, Allegheny chose a site already owned by the company.

The selected site, mined in the late 1970s had been reclaimed and covered with grass pursuant to the requirements of the Surface Mining Control and Reclamation Act. The existing soil was similar to that found on other mine lands that would be considered for reforestation projects. In addition, although the site had been reclaimed, it remained underutilized and would benefit from reforestation

Role of Partnerships

Allegheny decided to develop partnerships with local organizations also interested in reforesting abandoned mine sites. To improve chances of a successful project, the company encouraged partners to assume some level of ownership of the project. Allegheny distributed responsibility for project elements across stakeholders. The company felt partners helped to streamline project development and implementation.

Pilot Implementation

The project replanted 17 acres, with project partners helping with some planting. Fifteen acres were planted with pine and spruce seedlings (over 7,000 trees in total) and two acres were planted with warm season grasses. Fruit and nut trees were planted around the site perimeter for wildlife.

(Case continued on next page)

Case Example: Allegheny Energy's Reforestation and Sequestration Pilot (continued)

The entire plot was cleared with a brush hog before planting began. Because the land had already been reclaimed, the soil was compacted and needed to be made more suitable for tree growth. Allegheny used heavy-duty farm equipment to prepare the soil for planting. The company had a consultant take soil and fly ash samples to determine the amount of fly ash needed to enhance tree growth. The company used a local contractor experienced in plowing and discing reclaimed sites. Allegheny spent approximately $10,000 to treat the soil and plant the pines.

Students help plant trees at Allegheny's Limestone Run site. (Photo from Edison Electric Institute)

The site will need to be maintained for weed control for several years until the trees are established. The company will monitor survival rates for both evergreen trees and warm season grasses for several years, replanting as needed. Carbon sequestration rates will be assessed for evergreens starting in the fifth year after planting. The Pennsylvania Department of Environmental Protection calculated that at maturity, the trees at Limestone Run could remove 64 tons of CO_2 per year. Allegheny intends to register the carbon credits with the Department of Energy's voluntary greenhouse gas registry.

Lessons Learned

The most critical issue for this project will be the company's ability to measure and manage the carbon credits generated from the project. It is too early for Allegheny to measure or predict any financial benefits from this project (e.g., carbon credits, trading revenues). However, lessons learned to date include:

- Cost-effective project implementation will occur at sites with flat terrain and some soil coverage.
- State environmental agency regulations may limit the use of coal combustion products as soil amendments. Due to regulatory limits on arsenic (found in fly ash) in Pennsylvania, Allegheny could apply only 18 tons of fly ash per acre.
- Orders with nurseries for seedlings should be made well in advance.
- Fall may be a more optimal season for planting in some regions. Spring planting can be complicated by waiting for soil to thaw and drain and may not leave enough time before the summer dry season.

Given the success of this pilot, Allegheny is undertaking two additional projects. One project is a few miles from the Limestone Run site. The second is along the Cheat River in West Virginia. The project near Limestone Run will involve reclamation of an abandoned highwall in addition to reforestation.

The Cheat site will also remediate a highwall, but will involve the planting of hardwoods rather than pines. Allegheny is developing a legal agreement with the Cheat site landowner that will put the land in a conservation easement. This will prevent clear-cutting of the trees, but will allow limited timber harvesting on site. Allegheny's reforestation of the Cheat site is linked to a larger project involving a water quality trading program designed to clean up acid mine drainage in the Cheat watershed.
For more information contact Allegheny Energy: (http://www.alleghenyenergy.com/default.asp)

As seen in the Allegheny case, reclamation and reforestation of mine lands generates a wide range of potential benefits. However, the opportunity to develop and trade carbon credits will often serve as a key incentive for any for mine land reforestation project. Due to high costs associated with more traditional environmental controls, interest in market-based approaches to managing environmental issues continues to grow. The goal of such approaches is to encourage the private sector to undertake activities to improve environmental quality and ecosystem services such as climate regulation. Seen in the following case example, carbon markets need not be developed on a large scale. Trading can be simple and involve trades or agreements between two parties.

Case Example: Carbon Sequestration on Mine Lands in the Appalachian Region

In a project begun in 2000, researchers at Stephen F. Austin State University (SFASU) are studying the carbon sequestration potential of reforestation of abandoned mine lands throughout the Appalachian region. The study, funded by the Department of Energy, has multiple objectives:

- to calculate the profitability of planting and managing forests on former mine lands for both timber production and carbon sequestration;
- to calculate the total amount of carbon that can be stored on these lands; and
- to create a carbon credit market between landowners and utility companies.

The study focuses on the Appalachian region in part because of its potential to sequester large amounts of carbon. The region has a good climate for tree growth. In addition, the region contains vast mine land acreage, acreage that provides little or no economic, environmental, or other benefits.

Study Methodology

The SFASU research team conducted studies on abandoned mine lands planted with northern red oaks in Pennsylvania, West Virginia, Tennessee, Maryland, and North Carolina. Northern red oak was chosen because of its timber value and because it is commonly used on reclaimed mine sites. The research considered a number of variables such as soil quality, cost of site preparation, the local price for timber and pulpwood, and alternative rates of return on timber investments.

In order to determine the optimal harvest schedule and forestry management regimes for carbon storage, the researchers created computer models to evaluate millions of possible timber harvesting and carbon trading scenarios for their potential financial return. Two scenarios examined the profitability of managing reforested abandoned mine lands. The first scenario considered only the value of timber produced on reforested mine lands. The second scenario combined the value of timber production and carbon credits.

The analysis used six alternative rates of return. The model assumed the price of carbon to be $10, $50 or $100 for each additional ton of carbon that landowners sequester. The first scenario assumed the price of carbon to be $0 per ton.

Hardwood reforestation project at a mining site in Tennessee. (Photo by Office of Surface Mining)

Profitability of Forests on Abandoned Mine Lands

The research found that the costs of sequestering carbon on mine lands in West Virginia range from $7.20 to $40.50 per metric ton, depending on the cost of site preparation and the initial quality of the soil at a site. The research found that if there are no markets for carbon credits (i.e., price of carbon = $0), growing and selling timber is only profitable on sites with good soil at low anticipated return.

The research suggests that if there is no market for carbon credits, it would cost a landowner $7 per ton to store carbon on a site with average soil using a return rate of 3.5 percent. However, if a land-owner sells timber and is paid $10 for every ton of carbon, using the same return rate he could earn $4 for every ton stored, in net present value terms. With estimates that a carbon credit could be worth $30 per ton, the $10 per ton figure is conservative.

Case Example: Carbon Sequestration on Mine Lands in the Appalachian Region (continued)

Carbon Storage Capacity of Abandoned Mine Lands

The SFASU research found that the amount of carbon that can be stored at reforested sites is affected by site quality and harvesting schedules. Storage capacity ranged from 43 tons per acre of carbon on poor-quality sites to 58 tons on high-quality sites. Research also suggested that the profitability of forest management and carbon storage varies by state. Although Pennsylvania has higher timber prices, it is more profitable to grow trees in Kentucky. Trees grow faster in southern climates, thus the value of the timber increases more rapidly in Kentucky than in Pennsylvania.

Developing a Carbon Credit Market

Lessons learned from this research will be used to develop a carbon trading mechanism between individual landowners and utilities. Rather than a large-scale and formalized trading mechanism, the SFASU research will explore how to establish a simple carbon credit market between companies and individual landowners. Companies can offset their carbon emissions while landowners will get paid for growing trees and storing carbon on their land.

Toward that end, the SFASU team is disseminating the findings of their initial research to a variety of audiences interested in sequestration. Specifically, landowners and utilities will be provided with information on which future carbon trading decisions will be made. Information includes:

- the profitability of forest management and carbon sequestration (for specific tree species);
- the financially optimal forest rotation schedule for a particular tree species; and
- the amount of carbon that can be stored (given a particular tree species).

Future Work

The research will continue until 2005. With a model in place and tested on abandoned mine lands in West Virginia, the next step for this research is to determine the amount of carbon that can be sequestered and revenue earned per ton of carbon stored on former mine sites in Appalachian states. The research will also apply sector analysis to evaluate and quantify the local economic impact from reclaiming and reforesting former mine lands throughout the Appalachian region.

For more information, contact the Stephen F. Austin College of Forestry. (http://www.sfasu.edu/forestry/)

Carbon Trading and Banking in the United States

The case examples illustrate that forest carbon storage and sequestration may provide interested organizations with options for managing their carbon credits. Some organizations are developing markets to trade carbon credits. Other organizations are "banking"[4] their carbon credits, including forest-based credits, while waiting for emerging markets to be tested and further developed.

State Programs In the U.S., states have taken the lead in formulating carbon policies over the past decade. States have developed GHG registries or inventory programs that support carbon banking or the use of trading to reduce GHG emissions within a state's boundaries.

[4] A carbon bank is a program that enables organizations to keep track of a stock or supply of greenhouse gases in secure fashion for future use in a trading market.

Minnesota's Releaf Program promotes and funds the planting, maintenance, and improved health of trees in the state. The program's goal is to reduce carbon dioxide levels and promote energy conservation. Nebraska has tested sequestering carbon on farmland and passed legislation to explore the creation of carbon credits for agricultural activities. California's Climate Action Registry serves as a voluntary greenhouse gas registry to encourage early actions to reduce GHG emissions in the state. Appendix B provides additional information on public and private sector trading and banking programs.

Trading Carbon Credits

The success of the U.S. sulfur dioxide trading program in reducing acid rain, as well as other market-based approaches, has illustrated the potential benefits of emissions trading. As a result, support for market-based mechanisms to reduce GHG emissions continues to grow. In fact, the World Bank estimates that the value of a ton of carbon sequestered could range between $30 and $40 per ton in the U.S.; $70 and $100 per ton in European markets.

Landowners, GHG-emitting firms and other organizations have all begun to test and implement carbon offset markets. For example, the World Bank has established a Prototype Carbon Fund. (http://carbonfinance.org) This Fund invests in projects and programs designed to reduce greenhouse gas emissions through offsets and trading systems. Carbon trading markets are also being developed in the United States. The Chicago Climate Exchange is the first operating market in the U.S. for greenhouse gas emissions trading.

Chicago Climate Exchange (CCX)

CCX is a pilot trading program for emissions reduction and offset projects. CCX seeks to:

- demonstrate that greenhouse gas trading can reduce emissions across different business sectors;
- discover the price of reducing greenhouse gases; and
- develop a standard framework for monitoring emissions, determining offsets and conducting trades.

Building on EPA's acid rain program (SO_2 trading), CCX is a regional cap and trade system. CCX's goal is to reduce the greenhouse gas emissions of CCX participants by five percent below a measured baseline. The baseline for CCX projects is the average of annual emissions during the years 1998 through 2001. Carbon trading will apply to activities to reduce carbon emissions undertaken between 2003 and 2006. Forestry projects are an exception. Forest-based offset projects are eligible for trading in CCX if they were undertaken on or after January 1, 1990.

Tradeable credits can be generated by emission sources such as utilities, farm and forest carbon sinks, and a limited number of credits from renewable energy projects. Participants can seek to meet their reduction goals by reducing their own emissions or purchasing emission credits generated by other participants (offset projects or other emission reduction activities).

The Iowa farm bureau is currently developing carbon offset projects that will generate tradeable credits for CCX. Under this project, farmers in Iowa will undertake activities to generate tradeable emission credits. Activities will include conservation tillage, methane capture, and reduced use of nitrogen fertilizer on farmland. For example, farmers can generate offset credits at a rate of 0.5 metric tons of CO_2 equivalent per acre per year if those farmers commit to conservation tillage on their land between 2003 and 2006. The value of those carbon credits (a ton of CO_2) is determined through CCX. In February 2004, credits were being traded through CCX for $1.15 per ton of CO_2

For more information, contact the Chicago Climate Exchange. (http://www.chicagoclimatex.com/)

Banking Carbon Credits

Because emissions trading mechanisms for greenhouse gases are in the early stages of development and somewhat speculative, some companies that are planting trees on former mine lands are banking sequestration credits. Banking is an alternative to directly trading carbon on a market and recognizes that U.S. markets for trading carbon sequestration credits are emerging and may not develop fully for several years. Through the banking alternative, organizations can verify and "bank" carbon credits with a greenhouse gas inventory.

Several states have already implemented state carbon banks in the form of GHG registries. For example, California's Climate Action Registry, a public/private partnership, serves as a voluntary greenhouse gas registry to protect, encourage, and promote early actions to reduce GHG emissions. Massachusetts has developed a multi-pollutant strategy that includes CO_2 for major emitting facilities in the state. The Massachusetts rule requires applicable power plants to achieve a 10 percent reduction from 1997-1999 CO_2 levels. The rule provides the utilities an opportunity to secure credits through verifiable reduction measures such as carbon sequestration projects. At the federal level, the Department of Energy (DOE) oversees the largest greenhouse gas registry in the U.S.

DOE Voluntary Reporting of Greenhouse Gases Program

DOE's program provides organizations, in particular private sector entities, an opportunity to create a public record of their sequestration activities. Section 1605(b) of the Energy Policy Act, DOE's Voluntary Reporting Program provides guidelines that permit reporting on distinct greenhouse gas reduction activities, including:

- project-level emissions and reductions - emission reduction consequences of a particular action, such as a reforestation project.
- entity-level emissions and reductions - emissions and reductions of an entire organization, typically defined as a corporation.
- commitments to take action to reduce emissions in the future.

Under these guidelines, companies or individuals submit reports to DOE. The reports document the action being taken and the amount of greenhouse gases (reported in equivalent tons of CO_2) being avoided or sequestered. During 2002, 228 U.S. organizations reported that they had undertaken 2,027 projects to reduce or sequester greenhouse gases. A total of 412 carbon sequestration projects were reported for 2002, averaging 17,710 metric tons of carbon dioxide sequestered per project.

Independent verification will be necessary if an organization wants to trade its registered credits.

For more information contact: DOE Voluntary Reporting of Greenhouse Gases Program. (http://www.eia.doe.gov/oiaf/1605/frntvrgg.html)

Carbon Banking and Mine Land Reforestation

DOE's voluntary program, established by the Energy Policy Act of 1992, is designed to record project accomplishments and communicate innovative carbon sequestration approaches, including former mine land reforestation. (http://eia.doe.gov/oiaf/1605/frntend.html) Generally, the DOE greenhouse gas reporting guidelines suggest that sequestration activities can be quantified using the following four basic steps.

1. Define the boundary of the entity or project (acres of land reforested).
2. Estimate actual sequestration levels within a project boundary (the amount of carbon sequestered by trees on a site).
3. Estimate baseline sequestration levels (baseline, or reference case, sequestration levels are levels that would have occurred without the reforestation project).
4. Calculate the net level of sequestration (this calculation is the difference between actual levels and reference levels).

The Piedmont Energy Association case study, adapted from the DOE Forestry Sector Guidelines for the Voluntary Reporting of Greenhouse Gases, illustrates how a company might quantify and register carbon sequestration credits generated through abandoned mine land reforestation.

Case: Measuring Sequestration Credits Generated on an Abandoned Mine Land

Piedmont Energy Association (PEA), a coal mining cooperative owned by local utilities and independent power producers, wanted to reclaim an abandoned mine land with trees rather than the grasses required by the Surface Mining Control and Reclamation Act. Because the costs of establishing forests was only slightly higher than the costs of establishing grasslands, planting trees was a logical choice due to additional benefits of carbon credits. The company intended to report the change as a sequestration project to the DOE 1605(b) database.

The project required PEA to address three issues: (1) identify the appropriate reference case, (2) identify the sequestration levels of both the reference case and the project case, and (3) estimate the net sequestration associated with the project.

For the reference case, PEA asked what would have happened had the reforestation project not taken place. The answer for PEA was that absent the project, the land would have been grassland. One assumption was that the reference case would sequester a relatively small amount of CO_2 due to the growth cycle of the grasslands. A second assumption was that the project case would have higher levels of carbon dioxide sequestration due to yearly tree growth. The difference between the two would be the sequestration credits PEA would register in the DOE database.

PEA felt that the available data regarding growth rates of grasslands and forests on reclaimed mines was not applicable to its site. As a result, the company set up a field measurement plan with grassland and forested plots to represent its reference and project cases. The carbon uptake rates on each plot were measured each year for the first 3 years and will continue to be measured at 5-year intervals. The results from these test plots have allowed the company to extrapolate net sequestration levels for the larger reforestation project.

For more information, see the DOE Forestry Sector Reporting Guidelines.
(http://www.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/gg-v2-5-forest.pdf)

Additional information about private and public sector organizations involved in reforestation and carbon sequestration can be found in Appendix C.

Does Carbon Sequestration Make Sense for My Former Mine Land?

Landowners and companies should consider a number of factors when determining whether reforestation is feasible or suitable for particular former mine lands. Described in greater detail below, considerations include site demands and preparation, selection of tree species, regional variation, previous reclamation activities, economic implications, and ownership issues.

Site Demands and Site Preparation: Perhaps the most important factor affecting tree survival, growth, and productivity is the quality of soil on a mine site. (See http://www.fs.fed.us/ne/global/index.html.) Some mine lands can be productive forestry sites without significant work to prepare the site. However, mine soils may be too harsh for tree survival. These soils may be acidic and rocky and the sites are often steep, making tree establishment difficult. Compared to native soils, mine soils usually have limited organic matter content, low nutrient levels, poor water holding capacity, low pH, and many coarse fragments.

Reclaimed mine land is home to Christmas tree farms in many areas of the country. (Photo by Office of Surface Mining)

Compost has been shown to be a cost-effective tool for use at both large mining site and smaller urban areas with metal contamination from metal processing (e.g. foundry). Applying compost and biosolids to the surface of poor soil mine sites has at some sites shown the ability to improve soil conditions and enable revegetation. It can be used in a variety of situations, including wetlands, and can help the restoration and revegetation of sites. Composted biosolids can be effective because they will be free of pathogens. In addition, the metals that exist in biosolids are minuscule in concentration relative to the levels found at sites.

Selecting Tree Species: There is no universal recipe for successfully selecting and growing tree species on former mine lands. The most effective and successful tree selection will account for site-specific conditions. Early consideration of what tree species will be viable at a mine site will increase the potential for tree survival.

Previous Reclamation Activities: The Surface Mining Control and Reclamation Act (SMCRA), passed in 1977, has improved human safety and environmental quality at U.S. mine lands. The law mandates grading and shaping, which have eliminated many safety hazards routinely left behind by pre-SMCRA mining operations. However, mined lands reclaimed under SMCRA typically have heavily compacted surface layers that limit natural forest succession and impede reforestation. In most cases, post-SMCRA reclamation has resulted in the establishment of grasslands rather than forests. While aesthetically pleasing, these grasslands are seen as land uses that may not fully utilize a site's potential to support diverse and productive forests.

To help address some of these issues in SMCRA, the DOE's Office of Fossil Energy and the Department of the Interior Office of Surface Mining (OSM) signed a Memorandum of Understanding (MOU) in 2000 to promote the reclamation of abandoned coal mine sites through reforestation. By recognizing that there are multiple benefits to reforesting mine lands–restoration of clean water, recreational opportunities, commercial forestry, sequestering carbon– this MOU establishes a framework for cooperation between OSM and DOE. The MOU will help promote market-based approaches to reclaiming abandoned mine lands through reforestation.

Reestablishment of rangeland after reclamation provides forage for grazing animals, including these antelope on a North Dakota mine site. (Photo by Office of Surface Mining)

Regional Variation: In considering reforestation efforts across the country, it is important to recognize that there are no universal approaches for reforesting former mine lands or generating carbon sequestration credits on underutilized lands. Different regions in the United States offer unique challenges and opportunities for reclaiming and reforesting mine lands. Understanding limitations due to regional geography or climate will help inform how to best pursue a sequestration project at a former mine site.

Financial Decisions: Reforesting former mine lands with the intent of sequestering carbon can be expensive. However, economic returns over the long term may equal cost. For example, the cost to plant or replace trees and shrubs in the arid West can reach $1,000 per acre. With low survival rates for trees, any revenue from harvesting timber or trading carbon credits is unlikely to cover those potentially high costs. In addition, SMCRA requires only grass cover. Therefore, planting trees requires expenditures beyond traditional reclamation requirements. In addition, the more site preparation that is needed, the more financial risk is assumed with the anticipation that carbon credits will be profitable

Plantation Forestry - Sequestration projects developed through intensively managed commercial timberlands can generate unintended consequences. If reforestation and sequestration are focused solely on biomass accumulation, there may be a preference for single specie tree plantations.

Plantations have little in common with bio-diverse forests. Consisting of thousands of trees of the same species that are bred for rapid growth, and therefore rapid carbon dioxide uptake, these monocultures result in negative environmental impacts. Impacts can include loss of natural biodiversity, soil compaction, and reduced soil fertility.

Although there is little question that forests accumulate carbon in biomass as they grow, there is considerable uncertainty regarding the effect of forest management (thinning or harvesting timber) on carbon sequestration. . When trees are harvested, sequestration is affected for several reasons: carbon in the soil, roots, and understory will dissipate after harvest; and carbon in wood products may be released as those products undergo processing, use, and disposal. When a forest is clear-cut, carbon in the soil begins to dissipate, creating a large source of CO_2 emissions. While not completely eliminating these emissions, a sustainable timber harvest can help minimize these releases while keeping carbon sequestered in the harvested wood.

Measuring sequestration levels at former mine lands where timber is also harvested will be more difficult than at sites reforested only to sequester carbon. Therefore, if an organization combines timber harvesting and carbon credits at a former mine site, that organization will need to carefully measure and verify any tradeable carbon credits.

Ownership of Former Mine Sites: Determining site ownership can be a hurdle to reclamation and reforestation. For some former mine lands, uncovering legal ownership is straightforward, requiring only minimal title-searching. For other sites, ownership cannot be traced through legal documents and substantial investigation is required to locate and contact landowners or their heirs.

Once ownership is determined, other issues can complicate reforestation of former mine lands. For example, on sites where mining has ceased and the bonds have been forfeited by the company or owner, title to the land might belong to an original owner no longer in the area. If an organization plants trees on a site owned by someone else, it is important to have a legal agreement in place. As seen in the Allegheny example, having a legal agreement in place can ensure that newly planted vegetation is protected from activities, such as harvesting, that could impact the amount of carbon sequestered at a site. This can be critical if an organization intends to generate carbon credits on a site. Absent a legal agreement, timber could be harvested or the land cleared for other purposes and, sequestration benefits or credits would be more difficult to verify and might be lost completely.

Conclusion

With nearly one million acres of abandoned mine land in the Appalachian region alone, the potential benefits that are generated through reclamation and reforestation of these sites are significant. From supplemental timber revenues to the trading of carbon credits, reforestation of former mine lands can accrue financial benefits to local communities, landowners, and companies. Reforestation can also improve environmental quality locally (water quality, habitat restoration) and globally (climate change). In addition, complementary tools such as water quality trading, wetland banking, and land conservation could be combined with reforestation and sequestration activities to increase opportunities to return these degraded and underutilized lands to productive use.

While markets for carbon credit transactions exist, U.S. markets are speculative and are still being tested on a pilot project level. Furthermore, the definition of a carbon credit is not always consistent across markets or carbon banks. In spite of this uncertainty, public and private organizations are already exploring how terrestrial sequestration on degraded lands can play an important role in dealing with CO_2 emissions and reducing the impacts of climate change.

Uncertainties remain. Not all former mining sites will be suitable candidates for reforestation and sequestration projects. Regional variation, financial considerations, and site conditions will impact the feasibility of pursuing a reforestation and sequestration project on former mine lands. However, for many of these sites, carbon sequestration can provide an array of incentives for encouraging the revitalization of degraded and underutilized landscapes.

Contact Information

1. EPA's Abandoned Mine Land Team can provide communities with technical support and resources as they explore reuse opportunities available at former mine lands. For information about EPA's AML Team, please see the Web site at: http://www.epa.gov/superfund/programs/aml/
2. EPA also supports the reuse of former mine lands through the Superfund Redevelopment Initiative (SRI). For additional information see the (SRI) Web site at: www.epa.gov/superfund/programs/recycle. This website provides tools, case studies, and resource information on remediating and reusing Superfund sites, including former mine lands.